Journal of Industrial Microbiology (1996) 17, 505–511

The Convention on Biological Diversity: some implications for microbiology and microbial culture collections

BE Kirsop

World Federation for Culture Collections Biodiversity Committee, Biostrategy Associates, Stainfield House, Stainfield, Bourne, Lincs PE10 0RS, UK

The coming into force of the Convention on Biological Diversity has led to a series of discussions aiming to clarify its implementation. A number of uncertainties exist at the microbial level and there is a lack of awareness of the role played by microorganisms in ecosystem function. There is moreover a great lack of knowledge about the number of species of microorganisms that exist, their distribution, stability in the environment and intricate interactive roles. Conservation and use of biological material for sustainable environmental management are major issues. Specialist microbiological input into the debate is required to ensure that provisions made for national programmes are appropriate and practicable at the microbiological level. The Articles of the Convention of special relevance to microbiologists are listed and discussed. The role of microbial culture collections within the framework of the Convention is considered. The difficulties and uncertainties of conservation and study of microorganisms in their habitat (*in situ*) increase the need for *ex situ* conservation in microbial culture collections. The World Federation for Culture Collections plays a coordinating role with regard to expertise, information, training and the management and operation of microbial resource centres. It has the potential for providing a special interest Clearing House Mechanism for the support of the Convention.

Keywords: biodiversity; convention; biotechnology; culture collections; WFCC

Background

The Convention on Biological Diversity (CBD) [4] was opened for signature at the UN Conference on Environment and Development, Rio de Janeiro, 1992. It came into force in December 1993, following ratification by 30 countries. Since then, some 150 countries have ratified the Convention and a round of discussions is taking place with the aim of clarifying the implementation requirements and providing guidelines to signatory countries—Parties to the Convention.

The first meeting of the Conference of the Parties (COP 1) took place in the Bahamas in October 1994 [4], and the 2nd Conference (COP II) in November/December 1995 in Jakarta, Indonesia [5]. Many of the documents from these and other Convention meetings are available from the Secretariat of the Convention currently in Geneva, Switzerland, but due to relocate to Montreal, Canada in 1996. Many are also available online from the World Wide Web site of the Secretariat, using the electronic address: http://www.unep.ch/biodiv.html.

It is clear from the speed with which the above developments have taken place that there is substantial international concern about conservation of life on earth and its sustainable use. Parties to the Convention now have the obligation to implement the requirements at the national level. To this end, many countries already have national programmes in place and the necessary legal requirements to meet their obligations. Other countries have yet to establish programmes and may not have the required legal instruments to enforce aspects of implementation, or the necessary expertise (scientific, economic or legal) for making progress. It is clear that the Convention is an on-going process and that many of the uncertainties will only be clarified with time and following extensive discussion and further experience.

Microbiology and the Convention

Biodiversity is viewed both by the general public and by many policy makers as being confined to the animal and plant kingdoms. Thus, there is wide concern that endangered birds and tropical plant species be identified and conserved. Global efforts have been made to save whales, pandas and tropical rainforest trees from extinction or unsustainable use. Little attention has so far focused on the smaller living species such as insects, macrofungi or algae. Virtually no attention has been paid at the government level to the microflora of the world (bacteria, microfungi) upon which life on earth depends. Some of the reasons for this have been discussed by Zedan [15]. The main one—in addition to the 'lack of charisma' of most microorganisms—is identified as the lack of ability to give economic values to microorganisms, either *in situ* or *ex situ*, so that they are not incorporated into government budgeting procedures and are ignored as a valuable resource.

Scientifically, the recycling, nitrogen fixing and bioremediation functions of microorganisms are known to be fundamental to the survival and sustainable use of plants and animals, although large gaps in knowledge in environmental microbiology still exist. The direct effects of micro-

Correspondence: BE Kirsop, World Federation for Culture Collections Biodiversity Committee, Biostrategy Associates, Stainfield House, Stainfield, Bourne, Lincs PE10 0RS, UK
Received 16 January 1996; accepted 27 September 1996

organisms on the food chain are equally essential so that the survival of mankind is directly affected by microbial activity. The products produced by microorganisms and refined and purified by modern biotechnology provide a resource that is impossible to quantify *in situ* and only becomes measurable as a commercial pharmaceutical or chemical product as market values are applied. These uncertainties and difficulties make it easy to see why microorganisms, although included in the Convention, are largely excluded at the implementation stages, and why priorities in national programmes have not been directed towards the unseen, unquantified and unvalued microorganisms. Since all life ultimately depends on the activities of microorganisms, it is important that policies reflect this.

Articles of the Convention with major implications for microbiology

The Articles of the Biodiversity Convention raise a number of complex issues affecting a wide range of activities and specialist interests. These range from legal implications at the national and international level to the scientific execution of the aims of the Convention.

The major issues affecting scientific policies and performance are covered in the Articles of the Convention which are summarised below. The Articles not summarised include those covering definitions, the judicial and arbitration mechanisms, and protocols. For a fuller and definitive description of the Articles, readers are referred to the official text [4].

It should be pointed out that in each Article, the Contracting Parties (governments) agree to support the aims of the Articles 'as far as possible and as appropriate', allowing room for flexibility depending on national circumstances. Each Article also includes a statement indicating the special needs of developing countries. For simplicity, these common statements have not been repeated in each of the Articles summarised below. However, it should be borne in mind that the Convention is carried out through national programmes, and that the 'gene-rich' countries are often the poorest and most in need of additional support, both financial, scientific and technical, to conserve their national biodiversity.

A valuable analysis of the Convention has been provided by the World Conservation Union (IUCN) [8] in its 'Guide to the Convention on Biological Diversity'. This publication provides a large number of references.

Summary of articles of particular relevance to microbiology and culture collections

Article 1: the objectives of the Convention are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from the utilisation of biological resources.

Article 6: the Contracting Parties shall develop or adapt for the purpose of the Conventional national strategies, plans and programmes for the conservation and sustainable use of biological diversity.

Article 7: the Contracting Parties shall identify and monitor components of biological diversity important for its conservation; identify activities likely to have an adverse impact on conservation and monitor their effects; maintain and organise data derived from these activities.

Article 8: the Contracting Parties shall establish a strategy for the *in situ* conservation of biodiversity; develop guidelines for the promotion of sustainable management and sustainable development of areas of importance or under threat; develop legislation and maintain knowledge for the protection of conserved areas; contribute to the costs of such conservation, particularly in developing countries.

Article 9: the Contracting Parties shall complement *in situ* conservation by establishing and maintaining facilities for *ex situ* conservation and research on plants, animals and microorganisms; manage *ex situ* conservation so that resources are not threatened; cooperate in financial and other support for *ex situ* conservation, and in the establishment of facilities in developing countries.

Article 12: the Contracting Parties shall establish and maintain programmes for scientific training and research that contribute to the conservation and sustainable use of biodiversity.

Article 14: the Contracting Parties shall introduce procedures for environmental impact assessment; encourage the exchange of information; establish emergency response procedures.

Article 15: recognises the sovereign rights of States over their natural resources, such that the authority to provide access rests with the national governments and is subject to national legislation. Contracting Parties shall facilitate access to resources for environmentally sound use and not impose restrictions that run counter to the aims of the Convention. Access shall be by mutually agreed terms and subject to prior informed consent. The Parties shall endeavour to carry out scientific research, where possible in the country of origin of the resources. The parties shall take legislative, policy and administrative measures with the aim of sharing the results of research and development in a fair and equitable way.

Article 16: the Contracting Parties undertake to provide and/or facilitate access to and transfer of relevant technology (including biotechnology) for the conservation and sustainable use of biodiversity to other Contracting Parties, without causing damage to the environment. Access and transfer of technology to developing countries shall be provided/facilitated under fair and most favourable terms. The terms shall recognise and be consistent with the protection of intellectual property rights. The Parties shall take legislative, policy and administrative measures to facilitate technology transfer with the aim that the private sector facilitates access to joint development and technology transfer for the benefit of government and private sector institutions in developing countries.

Article 17: encourages the exchange of information from all publicly available sources, including the results from technical, scientific and socio-economic research, including where possible the repatriation of information.

Article 18: the Parties shall promote international technical and scientific cooperation; shall strengthen national capabilities and promote the establishment of joint ventures and research programmes.

Article 19: the Contracting Parties shall take the necessary measures to provide for effective participation in biotechnological research activities, particularly with developing countries that provide the biological resource, and where possible within those countries; the Parties shall take practical measures to advance priority access to the results and benefits arising from biotechnologies on a fair and equitable basis to the Parties of countries from which the resources derived. The access shall be on mutually agreed terms. Modalities shall be developed for the safe transfer and handling of living modified organisms that may have an adverse affect on the conservation and sustainable use of biodiversity; information available on these matters and any regulations in force shall be required to be provided.

Articles 20 and 21: the Contracting Parties undertake to provide new and additional financial resources to meet costs of measures needed to fulfil the aims of the Convention. A number of arrangements to accommodate particular difficulties (such as transition to a market economy) exist; a financial mechanism shall be set up that will operate under the authority and guidance of the Conference of the Parties for the purposes of the Biodiversity Convention.

Implications for microbiology and culture collections: lack of knowledge

The fundamental role played by microorganisms in maintaining life on earth is unquestioned by the scientific community [9]. However, the precise mechanism regarding interaction with other living entities in different environments leaves much yet to be learned. Moreover, existing knowledge of the extent of microbial diversity and its global distribution is minimal [3]. One of the reasons for the lack of knowledge is that the isolation and culture of microorganisms from the environment is difficult and existing technology only allows the study of robust species. Effort is now being directed towards the study and culture of the 'unculturables', using new molecular techniques [11]. As a result, the existence of new species, genera and even higher orders is being revealed, revising our earlier concepts of taxonomic hierarchies and up-grading our understanding of the role of microorganisms. The worldwide distribution of the newly discovered species is also unknown, although their physiological requirements give strong indications of where they might be found. Although many species seem to be ubiquitous, at present microbiologists cannot be sure.

With these limitations, the inventorying of the world's microbial diversity seems a long way off. Given the complex and ever changing nature of microbial activity it is questionable whether such a task is necessary or practicable. But the importance of microbial function to the earth's life support system demands that environmental knowledge is increased and microbial isolates are conserved for study and potential use. How, then, can policies for conservation be set?

Conservation *in situ*

The selection of sites for the protection of plants and animals will *de facto* conserve microorganisms associated with them. However, the conservation of sites where plants and animals do not exist (such as deep sea vents, high alkaline environments) are of equal significance for microbial conservation. Additionally, the highly polluted areas of industrial countries could be home to microorganisms with the ability to degrade toxic wastes and survive in hostile environments, making them strong candidates for biotechnological discoveries. It seems, therefore, that microbiological input into policy and conservation strategy debates is essential if unique microbial niches are to be incorporated into research programmes and the overall pattern of microbiological function is to become better understood. The automatic incorporation of microbiological input to conservation initiatives will do much to increase knowledge, as will support for such programmes as the All Taxa Biological Inventory (ATBI) [10].

The training element in biological conservation and taxonomy is crucial. Without an in-depth understanding of relationships between organisms in the ecosystem, conservation will be cosmetic, and could in the end be counterproductive with policies failing through ignorance. Many microbiological resource centres provide taxonomic training; culture collection organisations (national and international) organise specialist workshops on such matters as preservation technology, chemotaxonomy, environmental microbiology. The World Federation for Culture Collections (WFCC) has received substantial support for international training initiatives, both for courses and individual training. But beyond such specialist efforts, there is an overriding need for taxonomic teaching at the University level so that there are working taxonomists available for the major tasks ahead.

Conservation *ex situ*: zoos, botanic gardens, seed banks and microbial resource centres

Ex situ conservation of genetic resources is practised in all branches of biological conservation. Because of the uncertainties and complexities attached to *in situ* conservation of microorganisms (microorganisms may commonly replicate every 15–30 minutes and are adept at adapting to changed circumstances), *ex situ* conservation plays a very significant role.

In microbiology, the *ex situ* resources are the culture collections, gene-banks, microbial resource centres. These collections are in the main well established, well documented and well organised. Since they generally fail to fit neatly into perceived departmental responsibilities (holdings often covering medical, agricultural, industrially significant or teaching strains, perhaps), they are often also vulnerable to policy changes and cut-backs. As they are not cheap to set up and maintain, they are sometimes seen as convenient packages for making savings during times of economic constraint. Such measures are clearly in conflict with the aims of the Convention.

The Convention encourages the adoption of measures for the *ex situ* conservation of biodiversity, preferably in the

country of origin. In view of the costs of establishing effective and professionally run culture collections, there must be funding to support in-country developments and national needs must be assessed. In the long term it is essential to develop taxonomic and preservation expertise in all countries to support the isolation and inventorying activities on which other research programmes will be based. Only from an established knowledge base can appropriate access arrangements be established (see 'Who controls access?', below). However, because of financial limitations and the 'endangered species' status of microbial taxonomists, it may only be possible in the shorter term to build on existing microbial collections and systematics centres. To meet the requirements of the Convention and ensure equitable access and fair returns to the source country from the use of deposits, subsidiary legal agreements may need to be made.

Practicable application of this approach can be supported by the World Federation for Culture Collections (WFCC), which links existing culture collections and has a history of capacity building through training courses, workshops and publications. It has published a document, Guidelines for the Establishment and Operation of Collections of Cultures of Microorganisms [13]. Additionally, it has a unique database of some 500 culture collections throughout the world, which includes information on the species held by contributing collections, the scientific expertise available at each and the services provided. This database, the World Database of Collections of Microorganisms, WDCM, is maintained at the RIKEN laboratory, Saitama, Japan, and plays a valuable role in encouraging the documentation of existing centres so that unnecessary duplication of effort does not occur. A directory [14] is published from time to time, with UNEP and UNESCO support, and the database is also available online through the WWW address: http://www.wdcm.riken.go.jp/.

Members of the Federation believe that in view of financial limitations, a policy of specialisation, rather than duplication should be adopted in *ex situ* conservation strategies—although some measure of duplication for security purposes is desirable. The development of collections holding unique country isolates would strengthen the worlds' microbial library and allow easier monitoring of the source and use of strains, as required by the Convention (see 'Who owns the microorganisms', below).

The WFCC membership represents a technical resource for the support of the Convention. Taxonomic and preservation expertise are essential elements of the culture collections' infrastructure. In addition, many of the major collections serve as International Depository Authorities for the Deposit of Microorganisms that are the subject of Patent Procedures under the terms of the Budapest Treaty [1,12]. They are thus well informed about the complexities of intellectual property rights. Information about the Federation, its aims, activities, members, publications and conferences can be found at the WFCC WWW site, also maintained at RIKEN, using the URL: http://www.wdcm.go.jp/wfcc/wfcc.html.

In the plant and animal sectors, the *ex situ* conservation of rare species brings concerns of environmental loss as specimens are removed from the natural habitat for expert maintenance elsewhere. A balance must be drawn between *ex situ* and *in situ* activities. In the case of microorganisms, the chances of denuding the environment through sampling for *ex situ* conservation are remote.

The *ex situ* collections of microorganisms form an essential resource for the future that should be linked to research programmes so that maximum use is made of their expertise and valuable isolates are not lost through inexperience or lack of optimum preservation facilities. Partnerships between collections and research groups establish links between the habitat (source) and the liquid nitrogen cylinder (preservation system), optimising the expertise of each group.

Who owns the microorganisms: Who controls access?

Article 15 provides, perhaps, the greatest challenge to previously held attitudes. It sets aside the principle of 'common heritage' previously adopted widely and in its place accepts sovereign rights of States to their natural resources. This implies that all animals, plants and microorganisms living in a countries' territory are subject to the jurisdiction of that country, which has the authority to regulate and control access. This Article does not, however, grant property rights to the state, and the question of ownership of genetic resources remains subject to national law. Although it is not difficult to consider the ownership of plants and animals, this concept becomes more difficult to encompass as the living material becomes smaller in size.

Under the terms of the Convention, access to the natural resources of a state is the responsibility of the state and is governed by the laws of the state. In addition to the agreed terms (commercial, scientific, technical, legal) between Parties under which access may be granted, those requiring access may not do so without 'prior informed consent'. This means that Parties may not collect samples in the territory of another Party without ensuring their intentions are made known and mutually agreed terms have been reached, and that the consequences of these actions (as they affect diversity) are fully laid down and understood by the country of origin.

While it is feasible to control and monitor access to the elephants and orchids, or even the landraces of crop plants and species of bees, it is very difficult if not impossible to monitor access to microorganisms. In the first place, we do not know precisely what exists in any sample of the environment, so that there is no base line; in the second place, if we did know, we could not monitor access or trace the subsequent use. Although scientific organisation will operate in an open and professional way, following agreed procedures, any person returning home to his native state carries a population of non-indigenous microorganisms on clothes, baggage and as intestinal flora, so that monitoring of unofficial collecting is virtually impossible.

Again, it is almost impossible to prove that a new isolate comes from a particular host country. Subsequently, and after costly research and development in the laboratory, it may become impossible to insert a molecular tag to mark the strain. This allows industrial monitoring in the future, but does not help establish legal ownership by the country of origin.

Uncertainty regards the potential value of a microorganism at the time of sampling, together with the common introduction of additional genetic material (possibly arising from a different country of origin) into a natural isolate and strain development technology at the industrial level, all add to the complexity of arranging fair and equitable returns for negotiating parties in microbial prospecting.

A number of examples now exist of contracts developed between the supply country and the industrial developer. Well known arrangements, such as that between INBio in Costa Rica and the Merck company [7], will provide experience in the efficacy and fairness of such arrangements and it may be that draft guidelines will be developed for the use of countries without the necessary legal expertise.

It is important to note that Articles 15, 16 and 19 of the Convention do not apply retrospectively, although there is some discussion about this, particularly with regard to crops. Microbial strains deposited in culture collections before ratification are not affected. The Articles apply only to genetic resources that are provided by Contracting Parties that are countries of origin of such resources, or that have been acquired in accordance with the Convention. This means that culture collections maintaining isolates that are deposited after ratification of the Convention, and that come from countries of origin of Contracting Parties must be recorded as such and their future use must be logged.

This situation introduces complexities which will be compounded by the different dates of ratification of parties. Thus, an isolate may be considered 'retrospective' according to the collection holding it whose country ratified in 1994, whereas it may not be considered retrospective by the depositor whose country ratified the convention in 1993. Further complications arise when the culture in question is requested by a scientist from a non-ratified country where the Convention requirements do not apply.

Legislation or guidelines will need to be developed to ensure these requirements are met. Culture collections will have considerable responsibilities with regard to access and will need to pursue efficient and reliable recording procedures. Curators and the microbiology community will need to provide input to legislators to ensure measures can be technically and meaningfully enforced. Legislators are unlikely to know, for example, that deposited strains can exhibit strain drift under certain preservation regimes and with time will become 'different'. Regulations must reflect the special limitations of microbial function.

To aid this process, the WFCC is planning a workshop in 1996, in collaboration with the Forum for Industrial Microbiologists (FIM) to discuss these problems and outline the specific difficulties likely to be met in implementation of the Convention at the microbial level. It will endeavour to reach an informed view on the mechanisms required to be developed and to prepare an advisory document for COP III at the end of 1996 (now available through the WFCC WWW site).

Scientific need for access to *ex situ* microorganisms

As mentioned above, access to *ex situ* microbial resources will be subject to national legislation, since the Contracting Parties have the legal responsibility to administer access. This requirement may run contrary to existing practice of the majority of culture collections who, with the exception of strains held for patent purposes or deposited by industry for private use, have a policy of distribution to the scientific community without restriction. Indeed, the WFCC has as its aim the support of unrestricted flow of microbial material for research and teaching purposes. Restriction of this aim may seriously inhibit research studies and may lead to 'black market' distribution of substandard material, to the detriment of scientific progress and training.

Restrictive practices can best be overcome by ensuring easy, but regulated, access to microbial resources and by careful documentation of distributions by collections (sales, free gifts, exchanges) to safeguard ownership rights. Although the major distribution collections already operate well established and reliable documentation protocols, smaller collections and research collections not concerned in the main with distribution, will need to establish monitoring procedures. Additional measures to tag strains and their origins can be helped by a recommendation from scientific publishers to request submission of information on the unique strain identifier of cultures quoted in papers (preferably in the searchable abstracts), and deposit of referenced strains in established culture collections. Overall, a tracking system to monitor and record the flow of strains around the world must be adopted by all microbial resource centres, and not just those providing a professional supply service.

It may be considered appropriate to establish a special status for collections maintaining biodiversity isolates, rather as some collections have become International Depository Authorities for the deposit of patent strains under the terms of the Budapest Treaty, or maybe the functions could be combined. Parties to the Convention could identify appropriate collections within their territory to act in this capacity. Organisms requiring specialised maintenance expertise (such as methanogens, extremophiles) would need to be deposited in collections able to provide the necessary technical skills, so that technical limitations may affect the selection of appropriate depositories and 'twinning' and partnership arrangements may need to be set up to limit unnecessary duplication and conserve limited resources.

Technology transfer and capacity building

Technology transfer presents another area where the aims of the Convention raise uncertainties regarding their implementation. Scientific laboratories are required to provide access to and share benefits from technological developments with countries of origin in a 'most favourable' manner. Countries of origin will most often be gene-rich, resource-poor countries. The level of technology transfer is not defined precisely. At the same time, intellectual property rights are recognised. Collaborative arrangements must therefore steer a path between these aims.

The economic value of unnamed, unstudied microbial isolates is often limited. Much expensive research and development must be carried out before their potential can be assessed and realised. Countries of origin without such expertise are in a much stronger bargaining position if value

can be added to the material by carrying out identification or preliminary sorting. Building this capacity through joint research programmes that include training and technology transfer can lead to enhanced conservation programmes in resource-poor countries.

Know-how on the preservation and culture of environmental isolates—that may demand highly skilled procedures—must be shared with countries of origin. Here, the established and on-going training courses can play an important role, but funding should be made available to increase the level of this training activity. The establishment of regional training centres could be an appropriate mechanism to enhance capacity building in all regions where required skills are non-existent or inadequate.

Emphasis should be on specialisation rather than duplication to extend the breadth of the available microbial gene pool. The non-retrospective element of the Convention encourages the establishment of unique gene banks, rather than attempts to 'catch up' with established centres by duplicating existing holdings.

Modern telecommunication and information technology can greatly ease communications and information exchange among scientists and allow easy access to essential data. Policy makers are able now to search through a rapidly growing number of sites compiling information on biodiversity and microbiology. Access to these information sources is being facilitated by the establishment of such linking initiatives as the Biodiversity Information Network (BIN21) [2], and by a number of World Wide Web sites [6] providing interfaces for the casual user [see list of WWW sites]. A list of Web sites of interest to the biodiversity and microbiology communities is provided at the end of this article.

Conclusions

It is evident that the Biodiversity Convention will have a major impact on microbiology and microbial resource centres. Some of the implications are ambiguous at present and it is important that microbiologists are included in future discussions at the international and national levels. Only in this way can appropriate protocols and procedures be established that are microbiologically appropriate and practicable.

There are recognised needs for increased understanding of the role of microorganisms in ecosystems. Molecular methods need to be further developed in support of environmental study and strain identification; taxonomic expertise must be expanded as a priority. Well resourced centres of expertise for *ex situ* conservation are a long-term need, with strengthening of existing collections of microorganisms as a shorter term goal. Partnership arrangements offer appropriate medium term opportunities. The establishment of regional training centres for increasing taxonomic skills can do much to build capacity to meet the Convention requirements. Networking through the Internet is a major tool for speeding developments, encouraging international collaboration and distributing information cheaply and equitably. The WFCC can serve as a specialist scientific Clearing House Mechanism for microbial diversity, using the WDCM database and the expertise of the Federation members, as well as the on-going Federation training and publications activities as the basis for such support.

References

[Note: References marked with an * are also available online through Bioline Publications, Reports/Books Sections. URL—http:/www.bdt.org.br/bioline]

1 Bousfield IJ. 1991. Patent protection for biotechnological inventions. In: Living Resources for Biotechnology (Hill LR and BE Kirsop, eds), pp 95–147, Cambridge University Press, Cambridge, UK.
2 Canhos V, D Lange, BE Kirsop, S Nandi and E Ross. 1992. Needs and Specifications for a Biodiversity Information Network. UNEP, Nairobi, October 1992. World Resources Institute, Baltimore, MD, USA.
3 di Castri F and T Younes. 1990. Ecosystem function and biological diversity, Biology International Special Issue 22. International Union for Biological Sciences, Paris, France.
4* Convention on Biological Diversity Secretariat. 1992. In: Conference of the Parties Documentation on COP I. UNEP, 15, chemin des Anemones, CP 356, CH-1219 Chatelaine, Geneva, Switzerland.
5* Convention on Biological Diversity Secretariat. 1994. In: Conference of the Parties Documentation on COPII. UNEP, 15, chemin des Anemones, CP 356, CH-1219 Chatelaine, Geneva, Switzerland.
6* Edwards A, B Kirsop and D McKenney. 1995. The Internet and the microbiologist. Binary 7: 91–94.
7* Gamez R, A Piva, A Sittenfeld, E Leon, J Jiminez and G Mirabelli. 1993. Costa Rica's conservation programmes and National Biodiversity Institute (INBio). In: Biodiversity Prospecting: Using Genetic Resources for Sustainable Development (Reid W *et al*, eds), pp 53–67, World Resources Institute (WRI), Washington DC.
8 Glowka L, F Burhenne-Guilmin and H Synge. 1994. A Guide to the Convention on Biological Diversity. The World Conservation Union (IUCN), Gland, Geneva, Switzerland.
9 Hawksworth DL and RR Colwell. 1992. Biodiversity amongst microorganisms and its relevance. Biology International Issue 24. World Federation for Culture Collections (WFCC), Paris, France.
10* Janzen DH and INBio. 1993. Proceedings of the Norway/UNEP Expert Conference on Biodiversity (Sandlund OT and PJ Schei, eds), pp 100–113, Norwegian Directorate for Nature Management (DN) and the Norwegian Institute for Nature Research (NINA), Tungasletta 2, N-7005, Trondheim, Norway.
11* Stackebrandt E. 1994. The uncertainties of microbial diversity. In: The Biodiversity of Microorganisms and the Role of Microbial Resource Centres. pp 59–64, World Federation for Culture Collections, ICSU, Paris, France.
12 Weihs B and D Fritze. 1995. Patent protection in biotechnology—deposit of microorganisms and other kinds of biological material at the Deutsche Sammlung von Mikroorganismen. Microbiology Europe 3: 18–23.
13* World Federation for Culture Collections (WFCC). 1990. In: Guidelines for the Establishment and Operation of Collections of Cultures of Microorganisms. WFCC, ICSU, Paris, France.
14 World Data Center of Microorganisms (WDCM). 1993. In: World Directory of Collections of Cultures of Microorganisms, 4th edn, Riken, 2-1 Hirosawa, Wako, Saitama 351-01, Japan.
15 Zedan H. 1992. The economic value of microbial diversity. Proceedings of the WFCC International Congress for Culture Collections, Beijing, China, October 1992 (in press).

World wide web sites of importance

Biodiversity information
UNEP/CBD
http://www.unep.ch/biodiv.html

BIN21 Secretariat
http://www.bdt.org.br/

BIN21 Nodes

http://straylight.tamu.edu/bene/bene.html	(USA)
http://www.inbio.ac.cr	(Costa Rica)
http://fiss.org.ec/	(Ecuador)
http://www.wdcm.riken.go.jp/	(Japan)
http://life.anu.edu.au/	(Australia)
http://155.187.10.12/index.html	(Australia Ntl.Bot.Gdn.)
http://147.109.8.1/tpws.html	(Tasmania)
http://www.metla.fi/	(Finland)
http://www.icgeb/trieste.it/	(ICGEB, Italy)
http://www.wcmc.org.uk/	(UK)

Microbiology information

All Russian Collection of Microorganisms
http://www.stack.serpukhov.su/70/1s/db/vkm

Microbial Germplasm Database (USA)
gopher://gopher.bcc.orst.edu:70/1

Micro-NET (China)
http://sun.im.ac.cn/

Mycological resources
http://muse.bio.cornell.edu/taxonomy/fungi.html

The Microbial Underground (many links to other resources)
http://www.ch.ic.ac.uk/medbact/.index.html

World Federation for Culture Collections
http://www.wdcm.riken.go.jp/wfcc/wfcc.html

WDCM Database—500 culture collections of micro-organisms and cultured cells and their species holdings
http://www.wdcm.riken.go.jp/

Virtual Library
http://www.golgi.harvard.edu/biophages.html

General

Bioline Publications (online journals/reports etc)
http://www.bdt.org.br/bioline/

World Health Organisation
http://www.who.ch

National Center for Biotechnology Information (NCBI)
http://www.ncbi.nih.nlm.gov